ACTIVITY REPORT

January 2003

Natural Gas & Oil Technology Partnership

bringing department of energy national laboratories capabilities to the petroleum industry

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Drilling, Completion, and Stimulation Technology Oil and Gas Recovery Technology Diagnostic and Imaging Technology	Natural Gas Technology Upstream Environmental Technology Downstream Environmental Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Drilling, Completion, and Stimulation Technology

Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling (Halliburton and INEEL)

The Regenerative Combustion Source (RCS) bench checkout was completed and downhole source testing started in November at INEEL. Equipment problems during testing will require this experiment to be repeated.

The Capacitive Discharge Downhole Source (CDDS) prototype and a high pressure vessel were used to evaluate the effects of depth pressures on the CDDS seismic signature. Researchers were concerned that the source output signature would diminish to zero as the at-depth pressure went past the supercritical point of water (3200 psi) at ambient temperature. Discharges 1500 psi above vessel pressure lasting a couple of hundred microseconds were recorded past the supercritical point up to 4000 psi. Initial results indicate that there was no degradation of the seismic signature as the pressure went past the super critical point.

December's activities were very minimal. The Capacitive Discharge Downhole Source (CDDS) is in final assembly after high voltage power supply redesign and repair. Testing will start in the water filled well behind the Idaho Research Complex.

Acoustic Telemetry (MWD) (ABB, Electroacoustics Research Laboratory, Extreme, and SNL)

Highlight:

- Extreme Engineering and Baker Oil Tools continue development of commercial tools.

Work progresses with Extreme Engineering to develop a passive acoustic reflector. This will allow a more simplified field deployment of a commercial system. In support of this effort, project researchers also developed an algorithm to more accurately model the acoustic transmitter. In addition, researchers assisted Baker Oil Tools to retune their power amplifier to a higher frequency.

Development of Chemically Bonded Ceramic Borehole Sealants (GPRI, ANL, and LANL)

Highlight:

- Researchers lowered the thermal conductivity of the sealant by incorporating saw dust and hollow silica spheres.

The laboratory was closed for ten days during Christmas holidays. In addition, annual service of the laboratory equipment was carried out. The consistometer was serviced and could not be used extensively. However, some tests were ran prior to servicing the equipment, and the data is being analyzed now.

Compatibility of the Sealants for Permafrost Environment

In several tests, researchers confirmed earlier results on pumping time in permafrost environment. The temperature of testing was lowered to 30° F, at a pressure of 700 psi, and researchers could obtain a pumping time of three hours with an average consistency in Bearden units of only 13. This very low viscosity behavior is excellent for good pumping.

In addition, several samples were made to evaluate the thermal conductivity and specific heat of sealant formulations, because these are the important parameters that determine the success of a sealant for permafrost applications. Researchers are constructing the experimental arrangement to measure these parameters with these specimens.

The thermal conductivity of Ceramicrete with ash is 0.54 Watts/m.K which is low enough for this material to be an insulating cement. Researchers lowered the thermal conductivity by adding saw dust and hollow silica spheres. Up to 20 wt.% were added to each of these, which should reduce the theoretical thermal conductivity by 40%. The experimental thermal conductivity and spe-

cific heat in the laboratory will be measured. Experimental arrangements are being made for this purpose. The stabilized drill cuttings are fully cured now and were sent to ChevronTexaco for testing.

Future Plans

The tests will continue to firmly establish the properties of the insulating sealant as well as on high temperature sealant. Researchers are negotiating with University of Alaska Petroleum Engineering Department and a service company to test the sealant for permafrost regions. Hopefully, these should result in several applications in permafrost regions.

Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring

(DeepLook and LANL)

Highlight:

- A summary report of FY2002 field operations is 50% complete.

Project researchers initiated a preliminary draft report documenting the field microdrilling operations conducted in FY2002. Daily drilling reports and correspondence were reviewed and the first draft of the report is 50% complete.

Discussions with SNL continued to evaluate the feasibility of deploying their prototype polyurethane foam lost circulation materials in the microhole at Fenton Hill. This microhole was temporarily abandoned due to severe loss of drilling fluid returns. A successful field demonstration will allow researchers to reach the target formations and give SNL the opportunity for a small-scale field test.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlight:

- Researchers completed analysis of X-ray CT images.

Developing and testing process-based computational models of perforation and surge-induced clean up requires detailed experimental measurements of the process under controlled laboratory conditions. Recently completed experiments at the Center for Quantitative Imaging at Penn State University are providing unique data with which to test the recently enhanced computational models. Ongoing efforts are focused on completing the experimental program and refining the computational models to better predict experimental results.

Researchers completed analysis of X-ray computed tomography (CT) images obtained during flow tests in gas-saturated Berea sandstone cores perforated at 750- and 1500-psi underbalance. Analysis of a flow test in a liquid-saturated core perforated at 750-psi underbalance is in progress, and two additional cores have been prepared for perforating and flow testing.

Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Petroleum Composites, Puget Sound Rope, Shell, Whitehill Manufacturing, and ORNL)

No noteworthy progress was made in the current reporting period. Project funding for FY2003 has not been received, and carry-over funds from FY2002 are nearly exhausted. The project team will resume the testing and development of the strain sensor as soon as the FY2003 funding is approved.

Disposable Fiber Optic Telemetry System for Use With Coiled Tubing (GTI, CTES, and SNL)

There was no activity while awaiting new FY03 project funding.

Automatic Flaw Detection and Identification for Coiled Tubing (U of Tulsa, INEEL)

This month's project focus was on examination of coil tubing samples received from the University of Tulsa (UT). The UT samples contain a variety of artificial defects, and extensive examination of the individual defects using the magnetic flux leakage test equipment was performed. The defects were tested at different coil currents and travel speeds, and the data is being compiled into a library of defect types. The signals are being analyzed to determine characteristic signal features that can be used to classify defects.

Sensor assemblies were modified to add a radial Hall sensor. With this sensor addition, magnetic flux leakage can be sensed in the radial, longitudinal, and circumferential directions. Various defects are being tested at different coil currents and travel speeds, and the data is being added to the existing compiled signal database. These signal signatures are being compared to previous signals, INEEL-generated as well as those generated atUT, to determine characteristic signal features that can be used to classify defects.

Laboratory Study on Borehole Stability and Sand Production in Weakly Cemented Sand (ChevronTexaco, Shell, and LBNL)

Project researchers conducted grain shape analysis on different types of pure quartz sand. Optical microscope images of the sand grains were processed to quantitatively determine the angularity of the grains. For this purpose, a new method was developed based on the Fourier analysis of the grain radii distribution. This resulted in discrete, quantitative parameters that were very consistent with the qualitative description of grain shapes from visual inspections. These parameters should be directly related to the mobility and friction coefficient of sands, which have a large impact on the strength of rock formation and sand production.

In addition to the optical, 2D characterization of sand grain geometry, researchers also performed 3D X-ray computed tomography measurements on small samples of sand packs, using a new, high-resolution X-ray imaging machine (resolution 5–7 microns) developed for another project funded by the Fossil Energy Program. The objective of this measurement is to find correlation between the actual, 3D geometry of sand grains and the 2D grain geometry. Finding this correlation is important for practical purposes, since 2D grain geometry can be well described by the Fourier parameters determined from easily conducted optical microscope images of sand grains. At this stage, researchers have only collected multiple X-ray images of the samples. These images will be used to reconstruct the 3D images of the grains.

Development of Smart-Proppant Technology for Hydraulic Fracturing (U of Tulsa, and INEEL)

Highlight:

- Anaerobic and facultatively anaerobic thermophilic microbiological systems selected for enzymatic testing.

Work continues on the development of polymeric carrier systems for inclusion of industrial specified materials and systems. In addition to the previously reported systems, anaerobic and facultatively anaerobic thermophilic microbiological systems were selected, as were evaluation techniques for enzymatic testing. Initial growth of the organisms is in progress.

Specific organisms selected include two *Thermotoga* species, a *Caldicellulosiruptor*, and a *Geobacillus*. The organisms have growth optimum from

68–85° C (optimum enzyme temperatures are up to 105°C for the galactosidase and 92°C for the mannanase), and carry a combination of productive enzymes (e.g. beta-mannanase and alpha-galactosidase).

Application of High-Powered Lasers to Drilling and Completing Deep Wells (GTI, PDVSA, Parker Geosciences, Colorado School of Mines, and ANL)

Report not received.

Oil and Gas Recovery Technology

Improved Waterflooding Through Control of Brine Composition and Other Factors (BP Amoco, U of Wyoming, and INEEL)

The final report was printed.

Measuring Sucker Rod Pump Parameters Downhole (Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- New set of downhole sucker-rod pump sounds recorded.

Downhole sucker-rod pump sounds were recorded in the past by feeding the signal into the microphone jack of a laptop. A new set of triaxial sounds was measured. These were recorded at 4096 Hz using a 16-bit, filtered, simultaneously-sampled digitizer. The data includes axial and torsional vibrations using both a laboratory grade accelerometer and a capacitive accelerometer with a DC response. This data should show if correlation of axial and torsional sounds will allow the depth of the sound source to be located and should provide insight into the adequacy of dynamometer sampling rates.

Formation Logging Tools for Microboreholes (DeepLook and LANL)

Highlight:

- Final reported on the micro-inclinometer tool completed.

Project researchers completed the final report on the micro-inclinometer tool. The report includes: a description of the logging tool; specifications for the inclinometer-magnetometer sensor; a summary of the initial field test procedure and results; figures showing the calculated trajectory of the microhole based on a log of the hole from the surface and a log of the hole from the bottom of the steel conductor casing; and an appendix that includes sketches of the LANL-designed logging-tool housing and circuit schematics for the tool's telemetry system.

Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling (ExxonMobil, Schlumberger, UT-Austin, and SNL)

Project researchers recast the pore volume-pressure relationship in IPARS into an incremental form. By making this change, it becomes easier to implement an algorithm to control the frequency of geomechanics updates of porosity (frequency of calls to JAS3D). Such an algorithm is under development and is being implemented into the IPARS/JAS3D coupling approach.

The use of an incremental pore volume-porosity relationship also made the porosity coupling between IPARS/JAS3D more robust. Problems which had previously exhibited sensitivity to time step size and frequency of geomechanics updates ran without difficulty. The problems were subjected to varying intervals between geomechanics updates and showed no difficulties. Project researchers plan to repeat some earlier benchmark calculations to validate the algorithm.

In a recent paper, SNL compared three different techniques for coupling porous flow and geomechanics. The three techniques considered are fully coupled, iteratively coupled, and explicitly coupled. The study was done using the same simulator for all three techniques, which allowed for a direct comparison of their accuracy and efficiency. The results showed that all the methods were able to solve the four test problems when the right convergence tolerances and time step size are used, but the explicitly coupled approach was shown to perform the best in three of the four test problems. The explicit coupling approach is the technique used to couple IPARS/JAS3D.

Mechanisms of Oil Recovery and Validation of Corefloods

(ChevronTexaco, ConocoPhillips, and LBNL)

Highlight:

- New method of obtaining pore body-pore throat structure of the rock developed.

A new method of obtaining pore body-pore throat structure of the rock was developed. The algorithm was encoded and tested on packs of spheres and images of real rock. Using the new visualization tool reported in the previous issue, the results were compared with the known structure of the pore space. The results were good, regardless of the orientation of the analyzed sample and suggested the requirements to the image resolution given the grain size data. The upgraded version of the visualization software allowed researchers to compare the results of the algorithm with the void space structure of a real rock sample. For this purpose, high-resolution images of Fontainebleau sandstone were used. Again, the agreement was very good.

Project researchers developed an algorithm of analysis of the pore structure of a digital image that calculates a dimensionless capillary pressure curve and pore size distribution. This algorithm does not require extraction of a network; however, it allows calculation of the curve for drainage based either on invasion or on invasion-percolation method. The code was first tested on synthetic samples of sphere packs and then on digital images of Fontainebleau and Bentheimer sandstones. The obtained curves are very stable: they practically collapse for different parts of the samples, even for parts having significantly different porosities. The size of a representative rock sample was estimated based on the calculations. Testing the algorithm on computer-generated examples showed that increasing the image resolution significantly affects only the part of the curve corresponding to very low water saturations (at the limits of image resolution), whereas for medium saturations the results are remarkably stable.

Direct Simulation of Near-Wellbore Mechanics

(ChevronTexaco, Halliburton, Schlumberger, Shell, MIT, NM Tech, and SNL)

Highlights:

- Refinement and application of the 2D code, and the implementation of the 3D code continues.

Project researchers presented a project overview to Hughes Christensen Research, who has indicated that they will join the project's NGOTP technical review panel through their parent company, Baker Hughes. The review panel includes members from BP, ChevronTexaco, ConocoPhillips, Halliburton, Schlumberger, and Shell. In addition to the principle investigator, project staff contributing during this period included graduate interns Dave Boutt (NMT) and Scott Johnson (MIT), and postdoctoral associate Erik Strack.

Efforts were divided between the simulation study of sanding with the 2D code and the implementation of the fluid solver in the 3D code. Project researchers designed a suite of simulations to evaluate the sanding phenomenon in un- and weakly consolidated formations. In the initial parameter study, a number of simulations are being conducted with varying particle shapes, particle distributions, confining stresses, and fluid forcing. Sand production rates and cavity stability will be assessed for each model configuration through a quantitative analysis of particle erosion rates and a qualitative characterization of cavity geometries.

To investigate the role of cohesion (i.e., cementation), researchers are also reevaluating the current numerical bond implementation in the 2D code to verify that it captures the appropriate mechanical properties of natural cement. Finally, researchers began implementing the fluid solver for the 3D code. After evaluating several 3D lattice Boltzmann formulations for the solution of the governing Navier Stokes equation, a 3D lattice Boltzmann model that balances computational efficiency with numerical accuracy and stability was selected and implemented. The fluid solver will be validated in the next work period and then integrated into the 3D application framework.

Publications

Boutt D.F., B.J.O.L. McPherson, B.K. Cook, and J.R. Williams. "Application of a Directly Coupled Numerical Model of Fluid-Solid Mechanics," submitted to *Soil and Rock America 2003*, 2003.

Cook, B.K. "Coupled Discrete Element and Fluid Flow Model with Applications to Wellbore Stability Problems," internal Briefing to Hughes Christensen Research, January 23, 2003.

Cook, B.K., D.R. Noble, and J.R. Williams. "A Direct Simulation Method for Particle-Fluid Systems," submitted to *Engineering Computations*, 2003.

Johnson, S., J.R. Williams, and B.K. Cook. "Contact Detection Algorithm for an Ellipsoid Approximation for Discrete Element Modeling," submitted to *Engineering Computations*, 2003.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, Halliburton, Kerr-McGee, Shell, and SNL)

Technical work focused on the reservoir-scale finite element stress analyses task. On the basis of the enthusiastic response from the industry participants to the earlier work results, a refined suite of models with gradational meshes were developed that allow for increased stress resolution close to the boundary of the salt and non-salt formations.

Post-processing and data analysis efforts were expanded based upon the input of the participants, for example, to include determination of maximum and minimum horizontal stresses as well as maximum principal stress direction.

Following completion of the post-processing and data analysis, additional work will be performed on the reservoir-scale finite element stress analyses task as follows: (a) validation of the results for the four idealized geometrical models (spherical salt body, horizontal-lying salt sheet, salt diapir, and salt diapir with tongue) by comparison with field data from the Gulf of Mexico (GoM) in collaboration with industry participants; (b) a second set of simulations to investigate stress changes induced by production-induced pore pressure drawdown for each of the idealized geometries; and (c) additional parametric simulations to constrain model sensitivities due to, for example, reservoir versus far-field material properties.

Individual company meetings are scheduled to occur at Shell Exploration and Technology Co.'s New Orleans business unit as well as at ChevronTexaco's drilling center in Houston in February. A meeting is also scheduled at Anadarko to discuss their potential participation in the project.

Publications

A paper proposal entitled "Stress Perturbations Adjacent to Salt Bodies in the Deepwater Gulf of Mexico" was submitted for the 2003 Society of Petroleum Engineers Annual Technical Conference and Exhibition, to be held in October 2003.

Fredrich, J. T. and A. F. Fossum, "Large-scale Three-Dimensional Geomechanical Modeling of Reservoirs: Examples from California and the Deepwater Gulf of Mexico", O*il and Gas Science and Technology - Revue de L'IFP*, 57, p. 423 - 441, 2002.

An Integrated Approach to Assessing Seismic Stimulation (Aera Energy, ASR, BP Amoco, ChevronTexaco, ConocoPhillips, Halliburton, Marathon, OGCI, Piezo Sona-Tool, Schlumberger, Shell, UC-Berkeley, LBNL, and LANL)

Highlights:

- New fluid pump system procured for lab experiments.
- Invited article submitted to *The Leading Edge*.
- Expanded abstracts from Moscow stimulation conference available.
- Field system prepared for experiment at the North Burbank field.

OGCI tested and prepared their tool for large scale tests at the North Burbank oil field in northern Oklahoma. LBNL tested and prepared their tool for downhole and surface deployment of sensors (geophone and hydrophones) at the site. The monitoring of the OGCI tool will be conducted in early February.

Previous problems encountered with the 2-phase fluid pumping system at the LANL core stimulation facility are being solved by procuring a completely new system. It will allow continuous 2-phase fluid recirculation at constant pore pressure through the core samples.This will yield highly reproducible flow conditions and will eliminate pressure instabilities encountered with the old system.Calibration of the dynamic stress system using an aluminum standard is being performed while awaiting delivery of the new pump system.

As a result of interest generated at the 2002 Society of Exploration Geophysicists Development and Production Forum, an article was invited from project PI's to be submitted to *The Leading Edge* for a special issue on the D&P Forum.This article gives an overview and status report on several research and field evaluation programs on seismic stimulation that are active in the United States and Russia. It was submitted and should appear in the May 2003 issue, pending editorial review and approval.

Expanded abstracts from the Moscow conference, "Elastic Wave Effects on Fluids in Porous Media," August 2002, were compiled for public distribution. Twenty abstracts, along with a conference summary, program and topics discussed are available in a compressed archive file that can be downloaded beginning in February 2003 at *http://ees.lanl.gov/Resources/dssl.shtml*

High-Resolution Microseismic Monitoring of Reservoir Processes (ABB Offshore Systems, ChevronTexaco, Shell, and LANL)

Highlight:

- Analysis on seismic moment release for various Cotton Valley stimulation treatment designs completed.

Project researchers compiled and synchronized all seismic-moment data with the injection-volume data to derive the moment release per unit volume of fluid injected. Cumulative moment of tectonic seismicity was shown to be proportional to deformation rates. For induced seismicity, the value of moment release per unit volume injected should be close to the shear modulus of the rock. Huge deficits of moment released during the Cotton Valley treatments imply much of the deformation is not observed seismically. Presumably the deficit is manifest as a fracture opening that can be measured at lower frequencies, such as with tilt meters.

Direct Quantification of Uncertainties Associated with Reservoir Performance (ChevronTexaco and LANL)

Project researchers completed developing computational algorithms to parallelize the code for single-phase fluid flow in heterogeneous reservoirs. The equations for second moments (covariance and variance that quantify uncertainty of predictions) are independent of each other and can be solved on different computer processors, making it possible to conduct large-scale reservoir simulations.

Researchers continue to validate the code by comparing the proposed moment-equation approach against Monte Carlo simulation, using more complicated examples involving not only uncertainty on permeability of reservoirs, but also uncertainties on boundary conditions.

Diagnostic and Imaging Technology

Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation

(Input/Output and LANL)

Highlight:

- Radio-frequency telemetry link designed and fabricated for use at San Ysidro.

A radio-frequency telemetry link was designed and fabricated for use at San Ysidro. Researchers discovered that by "hardwiring" the signal from the shock accelerometer (mounted on the accelerated-weight-drop source) into the data acquisition system, the data was contaminated with the trigger pulse. The radio link seems to have alleviated this situation. After incorporating the hydrophone into the mix of sensors to be tested and burying them in a trench, researchers reshot a seismic line. The data has yet to be analyzed.

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, ChevronTexaco, ConocoPhillips, Fairfield Industries, GX Technology, Marathon, Unocal, and SNL)

Project is being closed out, final report will be issued.

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP, BP Amoco, ChevronTexaco, ConocoPhillips, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Fugro Geoservices, GeoCenter, Geophysical Development, GX Technology, Marathon, Mitchell Energy, Paradigm Geophysical, PGS, Shell, Unocal, Veritas DGC, WesternGeco, Society of Exploration Geophysicists [SEG], Stanford, U of Houston, LANL, and LLNL)

Highlights:

- New synthetic elastic data survey in SEG/EAEG salt structure defined.
- Synthetic elastic data being calculated in an additional model.

Project researchers designed a new phase, and began model calculations of 3D synthetic elastic data calculations in the SEG/EAEG salt structure. This design, called Phase II, has three differences from the initial (Phase I) calculations: 1) it models calculations to encompass the entire velocity model; 2) it introduces wells with VSP receivers; and 3) it reduces the spacing between Ocean Bottom Cables by half.

The initial Phase I calculations followed the GONII approach, which used a compute model that was one-quarter-size of the full model to carry out calculations. However, this also limited the maximum offset to about 6.5 km. By using the full model, the Phase II calculations allow a maximum offset that is nearly 13 km. Adding vertical seismic profiling to the model will provide model traces that will help evaluate the usefulness of wells in imaging salt bodies. Reducing the spacing between ocean bottom cables doubles the number of cables in the synthetic survey, and increases the usefulness of datasets for testing and calibration of seismic processing methodologies.

Synthetic elastic data are being calculated in another geologic model, the Marmousi II. This is an elastic version of the original (acoustic) 2D Marmousi model. Two phases of calculations will be run: one that includes the water surface as a free-surface reflecting boundary, and one that includes it as an absorbing boundary. The differences between the two calculations will show the effect of free-surface reflections in the data, which can be strong.

Project researchers presented modeling results from a series of simple models at a workshop on seismic modeling. A number of different modeling approaches were used to compute synthetic seismic data from the same series of models. The similarities and differences in the results from the differing methods were the topic of considerable discussion at the workshop, and may lead to follow-up efforts to better understand the strengths and weaknesses of differing modeling approaches.

Rapid Imaging of Interwell Fluid Saturations Using Seismic and Multiphase Production Data

(BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil, JNOC, Landmark, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

Highlight:

- Conjugate gradient and quasi-newton routines developed for the inversion of time-lapse amplitude changes.

Project researchers developed both conjugate gradient and quasi-newton routines for the inversion of time-lapse amplitude changes. The routines are being tested on a set of synthetic time-lapse amplitude changes. The algorithms compare well with performance of the current iterative linearized inversion algorithm. In particular, the convergence to a solution is faster, requiring fewer iterations. Because each iteration requires a reservoir simulation, this means fewer reservoir simulations are required overall. However, the iterative linearized inversion seems to result in a better fit to the synthetic amplitude changes. That is, it results in a reduced misfit to the amplitude changes. Researchers are also comparing the quasi-newton and conjugate gradient methods. At present, the quasi-newton method appears to outperform the conjugate gradient technique. Further testing is merited before researchers can conclude which method is optimal.

Project researchers devised a strategy for utilizing time-lapse derived pressure changes in order to estimate permeability reservoir. The technique shows promise and provides a linear mapping from pressure changes into arbitrarily large permeability variations. Thus, the method is direct, not iterative, and well understood numerically. Researchers are currently asking industry participants for time-lapse derived estimates of pressure change.

Offshore Oil Field Characterization with EM Methods

(Scripps, Texas A&M, and SNL)

Highlight:

- MT modeling results of the Gemini prospect presented at the American Geophysical Union meeting.

Accomplishments on this project focused on three areas in the last few months: modeling, reporting, and data collection. Project researchers extended the capabilities of the unstructured mesh finite element magnetotelluric (MT) modeling software to include calculation of the TM polarization mode in magnetotellurics. Comparisons between numerical and analytic solutions (Weaver et al., GJRAS, 1985) demonstrate excellent agreement.

Results for MT modeling of the Gemini prospect were presented at the recent Fall Meeting of the American Geophysical Union. Along with efforts from collaborators at Scripps Institution of Oceanography, researchers computed both 2D and 3D MT responses to shallow-rooted salt bodies. Results indicate that a simple differencing algorithm may help to constrain base-of-salt estimates from seafloor MT data. A more detailed analysis will be presented at an upcoming workshop on 3D electromagnetics (EM) to be held at the end of February in Adelaide, Australia. Lastly, with industry support researchers recently re-visited the Gemini site for additional data collection of the prospect. Using the new controlled source EM transmitter developed at Scripps, also with industry support, researchers collected CSEM data at 28 sites and added 15 MT sites to the existing database.

Innovative Wave-Equation Migration

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, ConocoPhillips, ExxonMobil, Fairfield Industries, GX Technology, Petroleum GeoServices, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Highlight:

- New method proposed that could improve imaging accuracy of common-azimuth wave-equation migration.

Project researchers are modifying the 3D wave-equation migration codes to deal with irregular receiver-distribution of the real 3D dataset from Unocal. The codes for using different Fast Fourier Transform (FFT) algorithms available on different computers are also being modified.

Studies of the stationary-phase common-azimuth wave-equation migration continue. Researchers will generalize the wave-equation migration methods developed earlier so that it can be incorporated into common-azimuth migration. Project researchers proposed a new method with the potential to improve imaging accuracy of common-azimuth wave-equation migration. Synthetic datasets will be used to test the new method.

Testing and Validation of High-Resolution Fluid Imaging in Real Time

(DeepLook, KMS Technologies, KJT Enterprises, U of Wisconsin, LBNL and SNL)

Determination of the sensitivity of seismic data recorded by a single-well seismic acquisition system to the presence or absence of fluid inclusions near the borehole is of primary interest for this project. Thus, SNL initiated, calculation of "seismic sensitivity traces" for the acquisition tool geometry and background elastic earth models utilized in the previous seismic forward modeling simulations. Recall that this tool consists of an axial force source and four three-component geophones distributed from 1–4 m offset distance.

A simple algorithm was developed to calculate the change in recorded particle velocity traces induced by placement of a point diffractor nearby. The material parameters of this point diffractor (elastic moduli, mass density, seismic wavespeeds, impedances) may be chosen to represent a fluid inclusion. Preliminary results indicate that the direction and range to the diffractor control the overall magnitude of the sensitivity, as expected from considerations of the source radiation pattern and the receiver reception pattern. Finally, the sensitivity of the recorded seismic data to a pertubation in the Lame elastic modulus "lambda" appears to be significantly smaller than the sensitivities to either mass density or shear modulus. Ongoing calculations are quantifying and systematizing these initial deductions.

Autonomous Monitoring of Production

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

In early December 2002, a field program was conducted at the Vacuum field site, accomplishing three goals: 1) A time-lapse survey was conducted over the 11-well pattern surveyed during the September 2002 and earlier visits. Processing of that data is in progress; 2) The survey well pattern was expanded to include nine additional wells, almost doubling the size of the survey region. These wells were added to the survey area to cover a region in which carvon dioxide (CO_2) expansion is occurring into an area in which only water has been injected. This will provide an opportunity to observe the new CO_2 front with essentially no increase in time or cost of the survey; and 3) Researchers prepared for the long-term, unmanned monitoring by laying wire for connection to all 20 wells (11 original and 9 new wells) in a semi-permanent installation. This installation will remain in place until after the monitoring phase.

The remotely-controlled electrical resistance tomography (ERT) data acquisition system was assembled, tested and utilized for data collection at a fixed location over a three month period. That test concluded in November and was

a great success-only 4 days of data were lost during the 110 days of the test. Two days were lost from battery failures and two days were lost from noisy data. No data were lost from computer networking problems. This test used a hard-line network for the communications. Researchers examined microwave and satellite networks and chose a system for installation at the Vacuum site. Hardware was ordered. The entire system will be configured at LLNL for a full test before moving the system to the field.

Anisotropic Properties of Compacted Clay-Rich Rocks

(BP Amoco, ChevronTexaco, ConocoPhillips, LBNL)

Work has stopped pending FY2003 funding.

Realistic Anisotropic Velocity Estimation in Complex 3D Environments

(BP Amoco, ChevronTexaco, ConocoPhillips, Kerr-McGee, Shell, TomoSeis, LBNL)

Highlight:

- Researchers developed a reverse-time prestack depth migration code.

Based on the new tilted transverse isotropy (TTI) acoustic P-wave equation, researchers developed a reverse-time prestack depth migration code. The TTI acoustic P-wave equation is a fourth-order partial differential equation. A finite difference scheme was used to compute forward and backward wave field. To reduce CPU time and memory, finite difference coefficients were derived based on minimizing the wave number response error between differential and finite difference operators.

Biondo and Shan (2002) proposed a simple method for computing angle-domain Common Image Gathers (CIGs) using prestack reverse time migration. The same method can be used to generate CIGs. The CIGs contain useful velocity information for updating the velocity model.

NMO Velocity in Tilted TI media

Tilted TI model is typical for sediments near the flanks of salt domes. The tilted symmetry axis may have a drastic influence on normal-moveout (NMO) velocity. To study this effect researchers generate synthetic data with a two layer model. The reflector is horizontal. With the non-hyperbolic moveout equation, *Vnmo* is estimated for different tilt angles. For this model, the *Vnmo* increases with tilted angle when tilted angle is less than 40 degrees. Then *Vnmo* decreases.

Joint Geophysical Imaging

(ExxonMobil, UT-Austin, SNL, and LBNL)

Detailed knowledge of fluid properties in oil and gas reservoirs is critically important to increased production and extending the life of proven reserves. One technique that shows promise in characterizing fluids is the use of complementary datasets (electromagnetic (EM) and seismic) to better characterize the reservoir. Seismic and electromagnetic data on their own do not have sufficient resolving power to provide the level of information required for imaging fluid properties, including water, oil and gas saturation levels. However, when such datasets are combined with a petrophysical model of the reservoir, it is anticipated that detailed fluid properties can be extracted.

Project researchers implemented a controlled source 3D EM inversion scheme based on gradient type methods to image the anticipated electrical conductivity distributions of offshore oil and gas prospects.Researchers are also completing an “amplitude versus offset” (AVO) seismic inversion code to image the reflectivity of the reservoirs. The work on the EM code showed that it is necessary to include a mask array to invert only over the known geometrical extent of the 3D reservoir to obtain reasonable inverted images of the spatially varying conductivity distribution, which is then correlated with saturation

changes. While results look encouraging, more work is needed in up weighting the long-offset data, compared to the close- and mid-offset data measurements. The long-offset data are the most sensitive to conductivity and hence, saturation changes in the reservoir. The next step in the project will involve the merging of the EM and AVO algorithms to invert for a common petrophysical properties of oil and gas reservoirs.

Project researchers are now in discussions with ExxonMobil for securing a marine dataset acquired over one of their prospects to test the joint inversion algorithm. Researchers are also in discussions with Norwegian contractor EMGS for a dataset acquired in the North Sea.

Partnership Office

Partnership Success

Partnership projects continue their efforts. Remarkable success have been achieved. During the FY03 industry review, one industry representative relayed that one Partnership project saved his company $33 million in cost for offshore production in the last year.

Partnership Funding

The Partnership completed the FY03 reviews and evaluations. The Partnership office developed funding recommendations based on last year's funding levels. These recommendations may not be applicable until the Senate and House appropriations are reconciled this winter. The funding for the Partnership may be from 30% of the FY02 amount to some other undetermined figure.

- The Partnership has been working on various contingency funding scenarios, which include decisions on whether new projects will start this year, whether sophomore projects maintain their previous year funding, and whether a minimum of funding is provided to second and third year projects to make it through the fiscal year.
- Current funding for existing Partnership projects will be expended in April.